A Nondestructive Acoustic Vibration System for Apple Firmness Assessment

*Chengqiao Ding\(^1\), Di Cui\(^1\) (1. Zhejiang University(China))

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Fruit firmness is closely related to the physical structures and mechanical properties, which is an important index at different stages of the food supply chain. In this paper, a loudspeaker-based excitation device was designed and compared with the traditional vibration shaker. The apples were placed on a string bag and driven by the swept sine wave signals ranging from 50 to 2000 Hz. And the response signal of apples was acquired by a laser doppler vibrometer (LDV) which was hung on the top of the excitation units. The test parameters of detection system were optimized in the single factor experiment, and the superior combination of test parameters were as follows: the aperture of sound source was 40 mm, the distance between fruit surface and loudspeaker was 95 mm, and the posture style was that the apple was placed with its stem upward. After the optimization of detection system, six vibration characteristics were extracted from the frequency response function (FRF) to establish the relationship with fruit firmness obtained by the puncture test. The correlation results showed the stiffness of apples was closely related to elasticity index (EI) and stiffness coefficient (SC), which was considered as a dependent variable in different regression models. Furthermore, the highest correlation coefficient \( r_p \) of the prediction set was observed in the BP neural network model by using EI, the peak value at \( f_2 \) and the peak area as the independent variables (\( r_p=0.914, \text{RMSEP}=0.561 \text{ N mm}^{-1} \)).